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Home College Series.

Number ❋ *Fifteen.*

THE MOON.

BY

REV. C. M. WESTLAKE, M.S.

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J. H. VINCENT.

NEW YORK, *Jan.*, 1883.

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THE MOON.

We may reasonably suppose the science of astronomy to have originated in the study of the moon. The sun, by its superior and unvarying brilliancy, would first attract and then baffle the attention of men. The lunar orb, perpetually changing, would, because of this peculiarity, become the subject of later and more constant observations. Man, even as a savage, must have been impressed by "the moon walking in brightness" and silently marching in stately grandeur among the stars; while her awesome changes of place and form inspired devout feelings, and led him to render divine honors to the Queen of Night. She soon came to be regarded as the emblem of change. Perhaps it was because of her regular irregularity that all lovers have sworn by her constancy, though only part of them have kept their vows.

In very early ages her comparatively rapid motion, in a circuit around the earth, afforded a convenient measure of time. Her contributions to modern exact astronomy are of the highest importance. It is probable that without her aid the law of gravitation would never have been discovered. Of all the heavenly bodies she is much the nearest and, consequently, the best known as to surface, configuration, and physical peculiarities.

I. The Moon as a Planet.

The moon's remarkable proximity is only comparative. Her mean distance from the center of the earth is about 240,000 miles. The use of the telescope, apparently, greatly lessened this distance. It is said Sir William Herschel employed a telescope of such great power that the moon seemed

to be within a distance of 40 miles. It is doubtful if a magnifying power of more than 1,000 can be practically available for astronomical purposes.

The apparent size of the moon.

Sometimes the moon appears smaller and sometimes larger than usual. This can be explained. The moon, in her elliptical orbit, answering to the attractive force of the sun, varies in the course of each monthly revolution from ten to twenty thousand miles on each side of her mean distance from the earth. This causes a corresponding variation in her apparent size. Again, the moon appears smaller at the zenith, though actually 4,000 miles nearer the observer than when at the horizon. This is a pure illusion, arising from the instinctive habits of the eye in judging distance and magnitude by intervening objects. Again, we are deceived by the brightness of the moon.

This fact dawns upon us when we see the crescent of the new moon, as part of a much larger sphere than the old moon, which it has been said, time out of mind, to "hold in its arms." Thus it appears the moon's disk covers a much larger space, in observation and calculation, than it would if it were not so bright. This effect of irradiation, as it is called, must be allowed for in exact measurements of the moon's diameter. The apparent size or angular diameter of the moon is about thirty-one minutes.

The real dimensions of the moon.

To ascertain the real diameter of the moon, we construct an imaginary right-angled triangle, whose perpendicular line is the known distance of the moon from the earth, and its base line half the angular diameter. From this we find it to be a little over one quarter of that of the earth, or about 2,160 miles. The surface of the earth contains about 196,870,000 square miles. The actual surface of the moon is rather more than two twenty-ninths of the earth's surface, and, therefore, is almost exactly equal to the areas of North and South America, exclusive of their islands. The earth is more dense than

the moon; so that, while in volume or bulk our planet is fifty times larger, her mass is eighty times greater than that of her satellite. With the naked eye large dusky patches are visible on the moon, a frequent observation of which leads to the conclusion that the same hemisphere is always turned to the earth. Obviously, the moon makes one revolution on her axis in the same time that she revolves around the earth, and thus always presents the same side to us. However, a small part of this, as well as a small part of the other, side slowly swings in and out of view. The following may throw light upon this balancing motion or "apparent rocking to and fro" of the globe of the moon. The moon's rotation on her axis does not exactly coincide with her revolutionary motion at every point of her orbit around the earth. As a matter of fact, when the moon is approaching perigee, or nearest the earth, her orbital motion is accelerated; and when approaching apogee, or farthest from the earth, it is retarded. "Her axial motion is uniform, while her orbital motion is not." In proportion to the difference between the orbital motion and the axial motion can we see alternately a little farther around on the eastern and western limbs of the moon. This alternation is called libration in longitude. Certain regions on the northern and southern limbs of the moon, also, alternately recede from sight and come into view. This is called libration in latitude, and is due to the fact that the axis of the moon is not quite perpendicular to the plane of her orbit; the poles of the moon being turned six degrees and a half alternately toward and from the earth. A kindred phenomenon to libration in longitude is called diurnal libration, since it occurs daily, and parallactic libration, since it is due to the point from which the moon is viewed; whether from the zenith, or eastern or western horizon, or any intermediate point. By these three librations two-elevenths of the moon's surface is swayed out of and into view; six tenths may be seen at one

Axial and orbital motions of the moon.

time or another, while the remaining four tenths are forever concealed from view. In accounting for these phenomena of the moon, we commence with her ellipsoidal form and elliptical orbit of slight eccentricity. The plane of this orbit is inclined to the ecliptic by an angle of about five degrees. The ecliptic is the circle described by the sun in its apparent motion around the heavens. The two points where the moon's orbit cuts this circle are called her nodes. These have a westward motion, and complete the circuit of the ecliptic in about nineteen years. The moon revolves around the earth from west to east. Moving at the rate of about twelve degrees a day, she completes the circuit of the heavens in about thirty days.

The phases, aspects, and periods of the moon.

The moon, revolving in her orbit, comes into different positions with reference to the earth and the sun. These different positions are called the aspects of the moon. The moon is a dark opaque globe; but the half that is toward the sun is always bright from borrowed light. The different portions of this illumined half, as they are turned toward the earth, constitute the phases of the moon. When the moon is in the same part of the heavens as the sun, or rather is between the earth and the sun, the aspect is that of "conjunction;" and, as the darkened side is toward the earth, the phase is a new moon, a corruption of "no moon." Where the phase of the moon is crescentic, with the convex side toward the sun and its horns toward the east, it is called "first quarter," and when with its horns turned toward the west it is called "last quarter." From the first quarter to the last quarter we may note the following aspects and phases. When the moon appears ninety degrees away from the sun, the aspect is at "quadrature," and the phase is that of a "half moon;" when past quadrature, the bright side appears as a "three-quarter moon" and is called "gibbous;" when the moon is in the opposite part of the heavens to the sun, the aspect is that of "opposition," and the

phase is that of the "full moon." The moon has two periods of unequal length, the *sidereal* and *synodical.* In making a complete revolution around the earth, the moon appears to pass around from a star to the same star again. The period of time required for this is about twenty-seven and one third days, and may be called the *sidereal month.* But, to pass from one *aspect* around to the same *aspect* again, while the earth is moving forward in its orbit, the moon must make more than a complete revolution. This occupies a period of about twenty-nine and one half days, and may be called the synodical month. Owing to the moon's eastward motion, she rises, on an average, fifty minutes later each day. If the moon was on the horizon at a certain hour to-day, she would be twelve degrees below the horizon at the same hour to-morrow; having traveled thirteen degrees in the meantime, or twelve degrees faster than the sun appears to move. The moon's latitude, nearness to the earth, and position in her orbit with reference to the equinoxes, effect more or less of a variation in this *daily retardation.* This is not likely to attract attention unless it occurs during full moon. The longest retardations for full moon occur in the spring, the greatest being in March. The least retardations for full moon occur in the months of August, September, and October, the least of all being in September. The "harvest moon" is the full moon of September, and the "hunter's moon" is the full moon of October.

The retardation of the moon.

II. The Moon as a Satellite.

Correctly speaking, the earth and moon are a pair of planets revolving around a common center of gravity. This common center, owing to the earth's greater size and weight, is located within it, at a distance of two thousand miles from that part of its surface which happens to be turned toward the moon. And in addition to this motion the moon, no less truly than the earth, revolves around the sun, whose attrac-

tion for each one of these planets is nearly the same in degree. Because of this, and their mutual attraction, the sun does not force them apart—they are traveling companions. Our planet, greater in size, has the stronger attracting power, yet enjoys the moon's beneficent ministrations; and hence the common expression, "The earth and her satellite." The analysis of the phases and aspects of our satellite, or peculiarities of lunar motion, has been carried to an almost unhoped-for degree of perfection by the most skillful observers and most acute mathematicians. Observation and calculation have been pushed to an equal point of delicacy to detect the exact proportion of the moon's influence, among others, in producing the tides, but without equally satisfactory results. The whole philosophy of tides has not yet been constructed. But there are certain very interesting facts which have been made apparent. The most ancient nations living near the ocean could not fail to have noticed the alternate rise and fall of the surface of the sea twice in the course of twenty-four hours and fifty-one minutes. They must also have observed the singular coincidence with this of the diurnal motion of the moon. The whole matter, however, remained enveloped in mystery, until the discovery of the law of gravitation made an explanation possible. The moon is now known to be the cause of the tides. In so far as the moon is responsible for the tides, they are due to her varying power of attraction. The moon is but thousands, while the sun is millions, of miles distant. Hence, as the power of attraction decreases as the square of the distance increases, it may be readily seen why the tides are the more largely controlled by the moon. Notwithstanding the sun's great distance from the earth, his attractive influence upon the tides is about four tenths as great as that of the moon, or as two to five. The earth produces a centrifugal—or center-fleeing—force by revolving about a common center of gravity. Hence it becomes depressed at the

The tides and the moon.

polar, and protuberant at the equatorial, regions. Thus of itself the earth contributes somewhat to the height of the tides by a kind of swinging off of the waters on that side farthest from the moon. We cannot precisely determine all the influences and their exact mode of interaction in producing tidal peculiarities. They are almost innumerable, and doubtless some of them elude detection. Others are known, such as the varying distance of the moon from the earth; its position, north, south, or at the equator; the varying distance of the earth from the sun; the direction and peculiar conformity of shore lines, and the meeting of tidal waves. These last two are found in conjunction in the Bay of Fundy, where the water rises to the unusual height of sixty and seventy feet. "At small islands in mid-ocean the tides never rise to a great height, sometimes even less than one foot; and the average height of the tides for the islands of the Atlantic and Pacific Oceans is only three feet and a half," while the average along the continental coast-lines is not less than four or five feet. The sea is at *flood-tide* when it is rising, and at *ebb-tide* when it is falling. When at its greatest height it is *high water*, and when lowest it is *low water*. At new moon, the sun and moon being on the same side of the earth, or in "conjunction," unite their forces, and we have the greatest ebb and flow, called the *spring-tides*. Their influences antagonize each other when the moon is in her first or third quarter, and we have *neap*, or *low tides*. We have the spring-tide, also, when the moon is in "opposition." Hence we have two spring-tides and two neap-tides occurring each month. Owing to the disposition of the waters to remain at rest, the moon's influence is not immediately felt; so that high tide occurs about three hours after the moon has passed over or beyond that point. In producing high tides at the points immediately under it, the moon draws the waters from the sides of the earth distant one fourth of its circumference, where of necessity there will be

low tides. But on the opposite side of the earth from the moon there will also be high tides.

"In one case, as the tide nearest the moon, the water is drawn from the earth; in the other, as the side farthest from it, the earth is drawn from the water." The chief cause of this is the moon's differing attractive influence on the near and farther side of our planet.

How strikingly the wisdom, power, and beneficence of Him "who hath measured the waters in the hollow of his hand" is illustrated in the tidal movements and their results! If the moon does not supply, at least it liberates and sets in motion tidal energy of a character most astonishing and beneficent to the world. From a practical point of view, the work done by the tides is of unspeakable importance. For six hours the world of waters surges simultaneously, in one resistless wave, to the east; and, after remaining at rest for a few moments, rushes back in one great tidal current to the west. This is continually repeated. By this ceaseless agitation the great body of waters, otherwise putrid and a storehouse of pestilential vapors, is kept pure, and also purifies the atmosphere. The beautiful white-crested waves cleanse the wind of its impurities, and send it back to the land more fit for the use of man. "The sea washes every shore, purifies every cove, bay, and river twice every twenty-four hours." Impurities are carried far from the shore and sunk into the depths of the never-stagnant sea. Great tidal waves rush up rivers and render such of these as are more shallow navigable, and thus facilitate the purposes of commerce. The flow and ebb of the tide transports heavy merchandise, which, if done by artificial means, would cost the city of London alone, thousands, and perhaps millions, of pounds yearly. One hundred years ago, the same city was supplied with water by pumps worked by tidal mills at London Bridge. By the aid of tidal mills the rise and fall of the water can be converted into any form of mechanical power. We do

not utilize the tides to the extent of their capacity. It remains for the future to develop this comparatively hitherto unworked power.

How wonderful that the moon, who is so remote, can perform for us so many important offices! Over the great distance of 240,000 miles she reaches out an invisible hand; and with its ever-open palm, through tidal forces and borrowed light, she ministers to the well-being of our world and its inhabitants. The superstitious notions of the moon's influence upon the weather, animals, plants, and food prepared at its particular phases, are wholly unsupported by philosophy or fact. But that "He hath appointed the moon for seasons," as also its beneficent disturbing influence upon the waters of the vast oceans, are matters of both philosophy and fact. How disastrous to the world would be the loss of its tidal energy! How much of human happiness is due to the presence of our beautiful lunar orb! How cheerless would be our long winter evenings if she was to disappear forever from our night-draped sky! Such a disappearance is highly improbable, at least so long as mankind needs her service. If the cometic origin of the moon be true, she may be lost to us, by some larger body than the earth passing near and carrying off our Empress of Night. Or at some day the earth may arrest and detain in his giant grasp another comet as a revolving satellite, and thus have two or even more moons, as is the case with some of the other planets. A more probable theory of the moon's origin is, that about the time that our globe, from thin nebulous matter diffused through space, condensed into its present shape, its satellite was formed in the same way, from fragments thrown off by the planetary mass. Hence the probability that the moon is composed of materials such as constitute our globe, and is of itself a dark body, shining only by reflected light.

Ideas of the moon's influence upon and relation to our world.

III. The Moon as a World.

Early notions as to physical constitution, etc.

The early Chaldean astronomers held that the moon was a globe, one half of which was made of fire, and which, by revolving upon its axis, presented its different sides in succession. This hypothesis was exploded when it was discovered that the bright portion of the moon is always that which is turned at once to the sun and to the earth. The theory which obtained about 640 B. C., that a portion of the moon's light is inherent, because of a dim globular light observed resting in the crescent or bowl of the moon, has since then been attributed to its true cause—the reflected light of the earth. Some of the Pythagorean philosophers taught that the moon is totally unlike the earth, and regarding her as a smooth crystalline body reflecting light as a mirror, they supposed the spots on her disk to be the reflection of the oceans and continents of our earth. Others have recognized in these spots the configuration of a human form. A French superstition that lingers to the present day holds this to be the image of Judas Iscariot, transported there for the betrayal of his Master. These spots bear a quaint resemblance to a human face. This idea is more than a nursery tradition, it is of the most venerable antiquity; but with the ancients the "man in the moon" is of the softer sex. We find in Plutarch a quotation from an early Greek poet which has received this translation:

Early notions as to surface, configuration, etc.

> "Over the orb shines a resplendent light,
> In the midst of which a damsel's face is seen,
> Whose cheeks suffused display her blushes bright;
> Her eye cerulean, or a pale sea green."

Telescopic revelations of the moon.

While fancy makes pictures of these unchangeable spots, and weaves them into poetic conceits, science, seeking their true explanation, reveals wonders surpassing those of pure imagination. The first users of the telescope supposed, from these spots appearing

smooth as water, that they were vast seas, and accordingly gave to them appropriate Latin names. But higher telescopic power showed these regions to have more or less of an uneven surface with permanent elevations and depressions, and thereby caused men to abandon the sea theory. These spots or plains, however, are comparatively smooth, because of the greater irregularities of the other portions of the moon's surface. Instead of regular mountain ranges and undulation of hill and valley, we find the surface of the moon differs from that of the earth, in having but few mountain ranges, there being a prevalence of crater-like irregularities and a general tendency to circular shape, as seen in its numerous ring-shaped mountains and plains. These plains or depressions are the dark spots seen upon the lunar disk; some of which sink lower than 4,000 feet below the general surface. "In consequence of the small gravitation of the moon, utter absence of the expansive power of ice shivering the cliffs, or the leveling power of rains, precipices can stand in perpendicularity, mountains shoot up like needles, and cavities three miles deep remain unfilled." Many of the crater-like mountains, with a diameter of more than fifty miles, have rings within rings. Often mountains of immense height are seen in these craters, mountains within mountains, seemingly constructed of volcanic matter, from former eruptions. These mountains vary greatly in size; some being so small that they can scarcely be detected with the most powerful telescope, and others again so large as to bear a sensible proportion to the moon's diameter. Its loftiest mountain, Doerfel, is 24,945 feet high. Our monarch of mountains, Mont Blanc, is surpassed in height by no less than 28 different mountains of the moon. The wonderful feat of measuring the lunar mountains is accomplished by ascertaining the time of revolution and observing the change of illumination; the daylight struggling with the dark along the terminator—the line of the moon's sunrise or sun-

set. In consequence of the slow rotation of the moon on its axis, its day and night must be each 304 hours long, or twenty-nine and a half times as long as ours. Each season consists of but three days and three nights, and twelve days and nights constitute a year of the same length as ours. For fifteen days the sun shines uninterruptedly, rendering the lunar day more scorching than the fiery breath of the sirocco. For fifteen nights darkness and intense cold succeed the moon's day. "And thus each of its long days will be in reality a summer and every night a winter—the morning twilight spring and the evening twilight autumn." Only on the moon there is no twilight, since it has no water to produce vapor, and the closest scrutiny fails to detect an atmosphere. Because of the atmosphere of our planet we see the image of a heavenly body a short time before it appears above, as also a short time after it disappears below, the horizon. But, instead of the same phenomenon, when the moon passes over stars they instantly disappear, and their reappearance is as sudden.

Day and night on the moon.

From this and other phenomena, which need not here be considered, we may reasonably infer the absence on the moon of all forms of life, resembling those with which we are familiar on the earth. In an early age the belief found favor that the moon was an inhabited world, like the earth. Some, taking into consideration the length of the lunar day and night, have thought the moon, if inhabited, must be by creatures fifteen times as large as terrestrial beings, and with architectural achievements correspondingly great. Others, again, upon the discovery of the absence of favorable conditions for life upon this side, have asserted the existence of these conditions upon the opposite side of the moon. The reasoning for this is now confessedly fallacious. Even with an atmosphere on the moon, there would be great difficulty in supporting life with any degree of comfort. Indeed, it would not be at all possible only under very

Is the moon inhabited?

peculiar circumstances. The moon has a very narrow temperate zone on the margin of its two hemispheres; but it is perpetually changing because of the moon's eccentric motions. To *live* on the moon is to *keep* in this zone. To do this, the lunarians, birds, beasts, reptiles, and insects, must be *constantly* on the move; at the rate of ten miles an hour in a sort of "Noah's Ark" procession.

Physical condition of the moon.

Many believe that the moon has not always been waterless and airless; but find difficulty in explaining the processes by which she reached her present condition. However, the opinion generally entertained is, that, as the moon's interior cooled, the water and air became soaked up in the porous lava of its substance. There are marked signs of former great volcanic activity on the moon; but it seems to have reached a burnt-out and chilled phase of existence many ages ago. The selenography and especially the mapping of the moon has reached such a point of perfection, that the least change in its surface, recognizable from the earth, could not escape notice. No change, in the visible configuration of the moon, has as yet been detected; and the supposition is that long ago it arrived at a terminal condition. Indeed, some are even disposed to say, "In the survey of its wonderful features, even in the smallest details, we are presented with the sight of objects of such transcendent antiquity, as to render the oldest geological features of the earth modern in comparison." It is quite probable as the moon looks to-day so will it appear to observers thousands of years hence. An ideal *view* of the moon-world and its phenomena may be pleasing and profitable. We pass no planets or stars in our journey to the moon; for it is the nearest of the larger heavenly bodies. In imagination we traverse the 240,000 miles of space and stand at sunrise upon one of the mountain tops of the moon. Over head is a cloudless sky, of inky blackness; the background of countless brilliant stars, and of the earth,

A visit to the moon-world, with a sight of its phenomena.

which is in appearance equal to many moons, and, when passing between the sun and the moon, is like a dark sphere in a circle of glittering gold and rubies. From the dark horizon, the sun suddenly darts his dazzling beams upon the tops of the mountains; yet for a time leaving the flanks and valleys still wrapped in total night. In the absence of air and vapor there is no gradual transition of night into day; no penciling streaks, no gilding and glowing, which make earth's sunrise so beautiful; yet there is increase of illumination as more and more of the sun's disk becomes visible above the horizon. The light, with a motion twenty-eight times slower than upon the earth, creeps down the mountain side, across the plain, and into the fearful blackness of the yawning crater.

Look where we may, we see vast regions of the wildest volcanic desolation, in which the ground is honey-combed with countless round pits or craters, some of them of immense depth and upward of four miles in diameter. On our right are steep gorges and precipitous chasms of appalling depth and blackness, and on our left cliffs, crags, and peaks tower far above us. We gaze upon the *débris* of long since expired volcanoes, but look in vain for a single vestige of past or present organic life. "No heaths or mosses soften the sharp edges and hard surfaces, no tints of cryptogamous or lichenous vegetation give a complexion of life to the hard fire-worn countenance of the scene. The whole landscape, as far as the eye can reach, is a realization of a fearful dream of desolation and lifelessness; not a dream of death, for that implies evidence of pre-existing life, but a vision of a world upon which the light of life has never dawned." In the midst of this dreary, desolate grandeur we look in vain for oceans, lakes, or seas; we listen in vain for the hum of industry or the sounds of wind or water, where there is no life to break the stillness, no breeze to murmur, "no brook to plash, no ocean to boom and foam." Let this desolate,

craggy, motionless world be filled with the activities of our own; and, in the absence of air, which is the medium of communication with the organs of hearing, it would still be a realm of dead silence. In vain would lips quiver and tongues essay to speak. The rattle of drums, the crash of musketry, the thunder of a thousand cannons would produce no sound in that airless world. At the close of the moon's long day we see, in glorious perfection, the red protuberances, crimson flame billows, corona and zodiacal light of the sun; as during the day we may have seen its spots and faculæ. During the lunar night periods of twenty-four hours each can be marked off by the successive reappearances of certain surface features of our globe. The positions of the constellations can be used for a similar purpose. Occasionally comets are seen in all their glory. The planets appear regularly every night; but meteors are never seen. Yet meteoric particles, sometimes singly and sometimes in showers, frequently smite the face of the moon. They meet with no resisting atmosphere, to melt them by its heat or break the velocity of their descent. These particles, under their initial velocity and the moon's attraction, crush into its surface with a force greater than that of a cannon ball striking a target. Kepler, though forced to abandon the theory after measuring the dimensions of some of the moon's craters, at first thought that they were artificial excavations in which the inhabitants sheltered themselves during the long and scorching days. They would be no less necessary as a protection from this bombardment of meteoric particles than from the frightful extremes of heat and cold.

NOTES.

"And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days, and years: and let them be for lights in the firmament of the heaven to give light upon the earth: and it was so."—GEN. i, 14.

"The sun to rule by day; the moon and stars to rule by night; he appointed the moon for seasons."—DAVID.

"When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him? and the son of man, that thou visitest him."—DAVID.

> "Who there inhabit must have other powers,
> Juices and veins, and sense and life, than ours;
> One moment's cold like theirs would pierce the bone,
> Freeze the heart's blood, and turn us all to stone."

"Some have asked whether the myriads of distant worlds were inhabited. It is not known. Perhaps it is a sufficient cause of their being that they should testify so effectually of God to every man, whether savage or sage, in all ages of time."—HENRY W. WARREN, D.D.

> "The poet's eye, in a fine frenzy rolling,
> Doth glance from heaven to earth, from earth to heaven;
> And, as imagination bodies forth
> The forms of things unknown, the poet's pen
> Turns them to shapes, and gives to airy nothing
> A local habitation and a name."—SHAKSPEARE.

THE MOON.

[THOUGHT OUTLINE TO HELP THE MEMORY.]

1. Value of moon to astronomy?
2. *Planet.* Distance from earth? Apparent size of the moon? How find real size? Compare with N. and S. America? How much of moon's surface never seen? Various notions?
3. *Satellite.* Power of sun on moon and earth? Cause of tides? Remarkable tides? Various kinds of tides? Value? Uses of moon to us?
4. *A World.* Theory of Chaldean astronomers? Various notions? Height of moon-mountains? Length of its day and night? Its seasons? Inhabited? Theory as to how moon came to be in its present condition? What one would see on a visit to the moon?

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